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of cream, without perceptible odor, and with the flavor of coconut milk. The fishermen state that this species, which is the one most common on the Atlantic coast, cannot remain under water more than four or five minutes. The color of the back, in some examples taken at Cape May Point, was a light plumbeous tint, but it appears that the depth of the color varies in different individuals, and deepens rapidly after life is extinct, especially if the specimens lie in the sun.

M. Paul Albrecht, in the *Pressé Medicale Belge*, 1884 (October), states that there are fourteen digits in the vertebrate foot. Seven of these are radial and tibial, one is axial, and six are ulnar and fibular.

M. Retterer, in a thesis presented to the Faculty of Sciences of Paris, describes the early stages of the limbs and feet in various mammalia. He shows that the primitive cartilages display the same numbers and character as the bones of the adults in a great many cases.

EMBRYOLOGY.¹

ON THE EMBRYOLOGY OF *LIMULUS POLYPHEMUS*.² III. — The stage under examination is that represented on Figs. 12 and 13, 14 and 15 (Plates III and IV) of my essay on the development of *Limulus* (Memoirs Boston Society Natural History, 1872). At this stage the oval blastodermic disc, with the six pairs of the cephalic appendages, is distinctly formed; the mouth is seen in a position in front of the first pair of appendages, and from it the primitive streak passes back to the posterior margin of the blastodermic disc or "ventral plate." The abdomen is separated from the head by a curved groove, as seen in Fig. 12 of my memoir.

The period examined is an interesting one, as while the cephalic appendages were well developed the abdominal appendages were not as yet indicated, nor the post-oral nervous ganglia.

The first point, which at once excited my attention, was the nature of the embryonic membrane, which I had previously regarded as the homologue of the amnion, and afterwards as the serous membrane of insects, but which Mr. J. S. Kingsley³ has found to be secreted from the blastoderm. A thin section (Plate XXIV, Figs. 1 and 5) shows that the membrane is very thick, structureless, the cellular appearance being confined to the external surface. This membrane is evidently secreted by the blastoderm; the irregular cell-like markings (see my second memoir, 1880, Pl. III, Figs. 14, 14a, 14c, 14d) are, so to speak, casts of the blastoderm cells, which with the marks of even their nuclei are impressed upon the membrane during the early stage in its forma-

¹ Edited by JOHN A. RYDER, Smithsonian Institution, Washington, D. C.

² Read before the American Philosophical Society, January 16, 1885.

³ The Development of *Limulus*, *Science Record*, II, pp. 249-251, Sept., 1884.

tion; after a while new matter is added to the interior which is structureless, so that the cellular appearance is only superficial. In my comparison of this membrane with the serous membrane, I certainly exaggerated its resemblance to the *serosa* of insects, as the latter is a much more delicate membrane, and with a characteristic appearance in Crustacea, the scorpion, myriopods and hexapods. The membrane in question appears to have its homologue, however, in the embryonic membrane of *Apus*, which we have described in a foot-note on p. 161 of our first memoir. It thus appears that this supposed point of resemblance in *Limulus* to the Tracheata is removed.

A longitudinal section of the embryo of *Limulus* is represented by Fig. 2. The section passes through the blastodermic disc (ventral plate) and the indications of the appendages, on one side of the median line of the body. The epiblast entirely surrounds the yolk, forming a thin layer with nuclei, the cell walls not being distinct, while the nucleolus consists of a number of granules. The nuclei are two deep only on the cephalic portion of the embryo. The blastodermic disc does not extend quite half way around the egg. The six pairs of appendages are well developed, increasing in size from the first to the last pair. The mesoblast is now well developed; the nuclei well marked, but the cellular walls more or less effaced. The mesoblastic arthromeres are now well indicated. The somatic cavities are well marked in each appendage; the somatopleure is from one to three cells deep; the splanchnopleure is formed usually of two layers of cells, and is more or less continuous at the ends of the somatic cavities with the somatopleure. The relations of these divisions of the mesoblast, which are destined to form the muscles of the limbs and the ventral aspects of the body, are represented in Fig. 3.

The mesoderm, as seen in Fig. 3, is now differentiated into three sublayers: 1, the somatopleure; 2, the splanchnopleure, and 3, a sublayer from which probably arises, in part at least, the connective tissue so remarkably developed in the head of *Limulus*; in its thickest portion at this stage this innermost layer consists of about eight series of cells, which are more loosely arranged than in the sublayers next to the epiblast.

The yolk granules are minute, the largest granules not more than twice as large as the nuclei of the mesoderm. The hypoblast cells are by far the largest cells in the embryo, and at once attract attention by reason of their size and their deep color when stained; the nucleus and nucleolus are well marked. At this stage no hypoblast cells could be detected in the yolk, nor any protoplasmic network connecting them. Those present formed a dorsal row ranged next to the thin epiblast over about one-quarter of the periphery of the ovum. In an earlier stage, however, the yolk granules are contained in distinct polygonal cells, forming a network extending through the yolk.

The abdomen has not yet undergone segmentation; the incipient steps are represented in Fig. 2, where there appear to be arising five mesoblastic segments (1, 2, 3, 4, 5). Between the first and second mesoblastic mass is a narrow cavity which sends a branch forward to the base of the abdomen, and a second obliquely downward and inward; at 2 and 3 in Fig. 2 there are narrow cavities or splits (somatic cavities?) which communicate with a longitudinal internal opening, which extends in a direction parallel to the under (now outer) surface of the abdomen. In this respect the embryo of *Limulus* is very different from that of the scorpion and spiders (see especially Balfour's Figs. 5, 6, Pl. XIX, and Fig. 15, Pl. XX), where the abdominal segments, with their appendages and somatic cavities are formed contemporaneously with those of the cephalothorax. The innermost mesodermic cells are now arranged in long cords, destined to form the ventral adductor muscles of the abdomen.

The mode of formation of the head and its shape at this time presents important differences from that of tracheate embryos. The procephalic lobes are not developed; the preoral portions of the head, *i. e.*, that part in front of the first pair of limbs is very small, short and narrow, merely forming the end of the oval blastodermic disc, seen in my earlier published figures. The structure of the preoral portion of the head (*procephalum* as we may term it), is seen in longitudinal section in Fig. 3, *pc*, to apparently consist merely of an extension of the postoral part of the head; with apparently one or two splits in the mesoderm (ms^1 , ms^2), the nature of which I do not understand; undoubtedly farther sections and comparisons will throw light upon it.

The first nervous ganglion is seen at Fig. 5 to result (as also first shown by Kingsley) in an ingrowth of the epiblast (*inv. c*); carrying into the interior a mass of epiblastic nuclei, which envelop the myeloid substance (*my*), which, as in older embryos, remains unstained by the carmine.

The mesoblastic nuclei stop at a large cell (*c*), beyond which are long incipient loose muscle-cells with a few scattered nuclei.

The procephalum terminates abruptly, forming, as seen in our earlier figures already referred to, the end of the blastodermic disc.

The absence of the procephalic lobes in the embryo *Limulus* of this stage seems to us to be a very significant fact, and to point to the early divergence of the Palæocarida from the stem leading up to the Tracheata, and especially the Arachnida. Metschnikoff's researches on *Scorpio*, with those of Claparède, and of Balfour on the spiders, and those of Sograff on the myriopods, show that this is a fundamental and early attained feature in these types. Their absence in *Limulus* shows how little its embryo has in common with tracheate embryos. At the same time the general mode of formation of the blastodermic disc (ventral plate) of

Limulus is much like that of the spider, as seen in the mode of origin of the mesoblastic segments and the probable origin of the hypoblastic cells. There is a superficial resemblance between the embryo of *Limulus* and of the spider, as may be seen by a comparison of our Fig. 2 and Balfour's Fig. 15. Without much doubt the Tracheata and Palæocarida, as well as Crustacea Neocarida, branched off from a common ancestor, but the more important morphological points show that the terrestrial, air-breathing tracheates were a much later branch of the arthropod tree than the marine branchiate Palæocarida and genuine Crustacea. Probably the Palæocarida (*Limulus* and other Merostomata, and Trilobita) were the earliest arthropods to appear; after them arose the Crustacea, perhaps at nearly the same time the Arachnida, and finally the Myriopoda and the winged insects. Without much doubt the earliest branchiate forms were our *Protocyclus*,¹ the ancestor of the Palæocarida; and a protonauplius form, the forerunner of the Crustacea; these were marine, perhaps branchiate organisms, with a few pairs of simple oar-like swimming appendages either around or just behind the mouth, and which were free-swimming or creeping forms; the *Protocyclus* was, perhaps, a solid oval creeping animal living at the bottom on mud or sand. The branchiæ probably became first developed on the limbs of the free-swimming Protonauplii, as they needed, owing to their great rapidity of movement, the means of rapid aëration of the blood; while in the heavily molded less oxygen-consuming *Protocyclus*, the evolution of gills was somewhat postponed. The steps from *Protocyclus* to *Agnostus* was not a very long one. The oldest arthropods, notwithstanding the recent discovery of a Silurian scorpion, were trilobites.

The following conclusions are drawn from a study of the stage of *Limulus* here figured.

The fact that the embryo *Limulus* had at first no abdominal appendages (uropoda), whereas there are temporary abdominal appendages in the tracheates, shows that *Limulus* in this important respect has little in common with the Arachnida, Myriopoda or Hexapoda. On the other hand in the embryo Crustacea the cephalic limbs are first indicated; the nauplian limbs as well as the zoëan appendages being cephalic; the uropods not appearing until after the Crustacea leave the egg.

These facts indicate that *Limulus* probably descended from a type in which there were cephalic appendages only, and no abdominal appendages. The absence of a serous membrane, of an amnion, and of procephalic lobes, of temporary embryonic abdominal appendages (at the stage above described); also of protozonites (seen in the early embryo of the scorpion and spider) tend to prove that the embryo of *Limulus* has little in common with that of Tracheata.

¹ See Development of *Limulus*, 1872, p.

On the other hand the earlier stages in the embryology of *Limulus* resemble those of Crustacea in the absence of the procephalic lobes; in the primitive development of cephalic appendages alone; the comparatively early appearance of the branchiæ of *Limulus* in the stage succeeding that figured in this essay, shows that the *Limulus* probably never had any genetic connection with a tracheate arthropod.

On the other hand, the tracheate features of mesoblastic somites are also seen in the worms, in *Peripatus* and in Annelida.

It appears that the embryology of *Limulus* is scarcely more like that of tracheates than Crustacea; it is a very primitive type standing nearer the branchiate arthropods than the tracheate, but on the whole should be regarded as a generalized or a composite form, which with its fossil allies, the Eurypterida and Trilobita, form a class by themselves with a superficial resemblance to the Arachnida.

It seems to us that the above-mentioned characters, which separate the early embryo of *Limulus* from the tracheates, are as important, if not much more so, than those of the absence at first of an archenteric cavity or differences in the mode of origin of the mesoblast, noted by Mr. Kingsley in his brief paper on the development of *Limulus*. In these general, primitive embryonic characters *Limulus* appears to be as nearly allied to the annelids as to the tracheates; and too much dependence should not, it seems to us, be placed upon them in seeking to establish the true relations of the Palæocarida among the arthropods. In the higher worms the two longitudinal mesoblastic bands split into somatic and splanchnic layers (Kowalevsky). In *Mysis* Metschnikoff states that the mesoblast becomes broken up into distinct somites (Balfour's *Embryology*, 1, 436). If so, then this character is not one of much importance to separate *Limulus* from the Crustacea. The ultimate origin of *Limulus* from the same stock as that which gave rise to the modern annelids seems not improbable.

EXPLANATION OF PLATE XXIV.

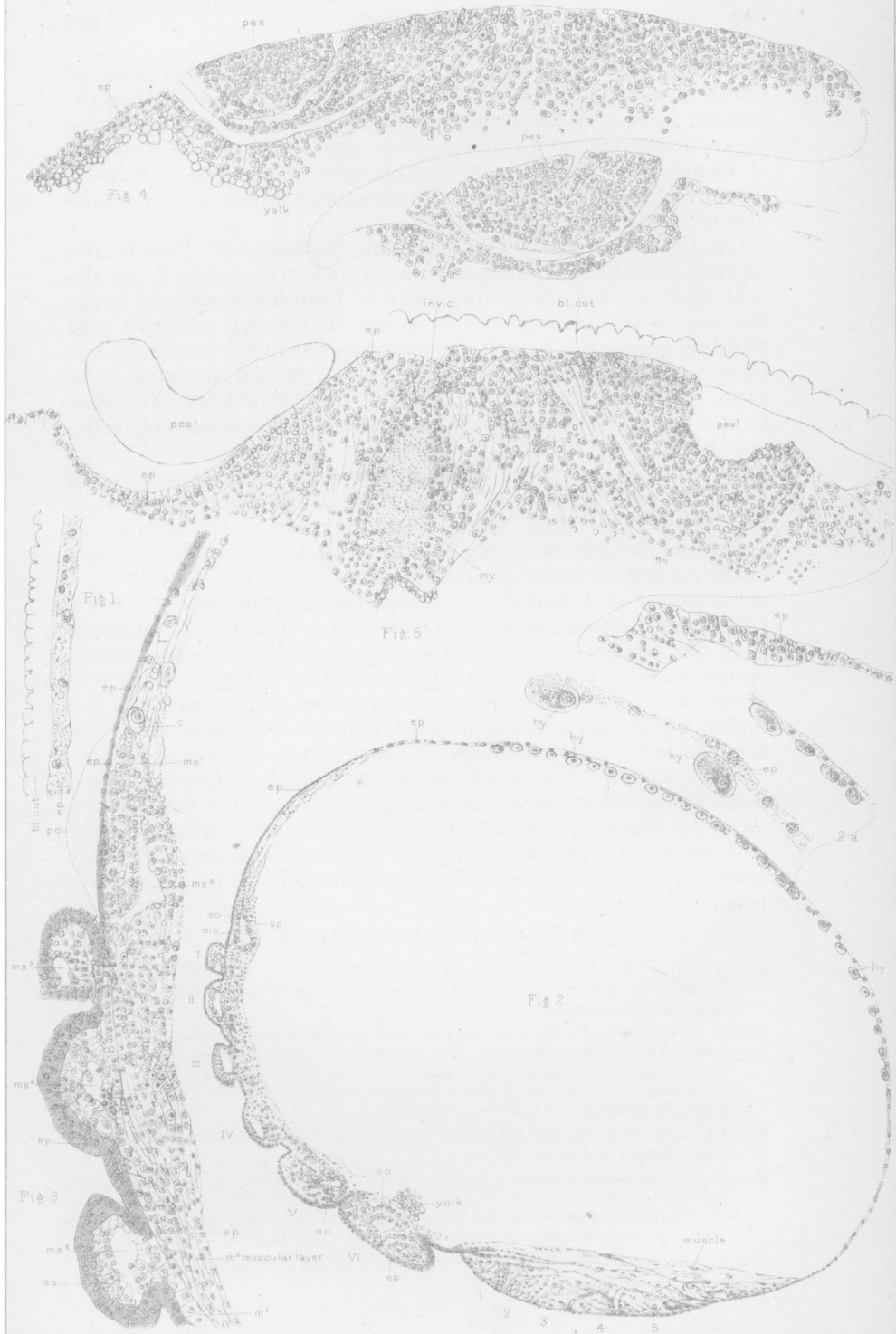
FIG. 1.—Blastodermic cuticle (*bl. cut*) lying upon the epiblast (*ep*). The nuclei scattered through the latter; the nucleolus in these as well as the mesoblast cells, consisting of a number of granules. $\times \frac{1}{3}$ A.

FIG. 2.—Longitudinal section through an embryo before the appearance of the abdominal appendages, but after the rupture of the chorion; the section passes through the six cephalic appendages (1-vi), showing the somatic cavities (*ms*), the splanchnopleure (*sp*), and somatopleure (*so*); 1-5, the indications of the five primitive uromeres; *hy*, hypo- or ectoblast. $\times \frac{1}{3}$ A.

FIG. 2a.—Showing the relations of hypoblastic cells (*hy*) to the epiblast (*ep*) in the dorsal region of the embryo.

FIG. 3.—Longitudinal section of the head and the first three appendages; *ms*¹, *ms*², first and second somatic cavities in the preoral region of the head. This figure also shows the relations of the splanchnopleure and somatopleure to the epiblast. *c*, large distinct cell in preoral region. $\times \frac{1}{3}$ A.

FIG. 4.—Transverse section through the head, including the appendages. $\times \frac{1}{3}$ A.



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FIG. 5.—Transverse section through the head, showing the invagination and thickening of the epiblast to form the brain; *my*, myeloid substance of the ganglion. $\times \frac{1}{3}$ A.

All the longitudinal sections are from the same egg, and the transverse sections from another. The figures were all drawn by the author with the camera.

—A. S. Packard.

PHYSIOLOGY.¹

SCIENCE VS. THE "ZÖOPHILIST."—The believers in physiological experiment upon animals as a means for increasing our knowledge of the body will all heartily indorse Professor Martin in his vigorous "castigation" of the truth-distorting and fanatic *Zöophilist*, an English sheet whose ostensible object is the prevention of cruelty toward animals. People who are opposed to what is popularly known as "vivisection," may be divided into two classes, the reasonable and the unreasonable. It is the duty of physiologists to maintain the respect of the former class by the presentation of the abundant arguments which defend the use of the lower animals, under proper conditions, for scientific purposes. The latter class could probably never be completely silenced except by a course of unresponsive contempt, but for all that one must occasionally be pleased to see a fool get his just deserts.

CONDITIONS MODIFYING THE DIASTATIC ACTION OF SALIVA.—Messrs. Chittenden and Smith have extended the valuable researches of the former upon the diastatic action of saliva. The following are their conclusions:

"1. The diastatic action of saliva can be taken as a definite measure of the amount of ferment present only when the dilution of the saliva in the digestive mixture is as 1 : 50 or 100. The limit of dilution at which decisive diastatic action will manifest itself with formation of reducing bodies is 1 : 2000–3000, under the conditions previously given. 2. The diastatic action of neutralized saliva is greater than that of normally alkaline saliva. The difference is particularly noticeable where the dilution is as 1 : 50 or 100, and is apparently out of all proportion to the amount of alkalinity. 3. Sodium carbonate retards the diastatic action of saliva in proportion to the amount of alkaline carbonate present. The percentage of alkaline carbonate, however, which hinders diastatic action can be designated only for definite mixtures and not in a general sense, being dependent on the dilution of the saliva and the consequent change in percentage of proteid matter. 4. The destructive action of sodium carbonate is materially modified by the dilution of the saliva, becoming greater the more the fluid is diluted. This result is due not to simple dilution but doubtless to the diminished amount of proteids. 5. Neutral peptone has a direct stimulating effect on the diastatic action

¹ This department is edited by Professor HENRY SEWALL, of Ann Arbor, Mich.